THE INFLUENCE OF THE FLOW DYNAMICS ON DEPOSITION UNIFORMITY IN TOWNSEND DISCHARGE AT ATMOSPHERIC PRESSURE

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Abstract. This paper deals with the role that plays the flow dynamics in obtaining layers with thickness inhomogeneities in the case of atmospheric pressure Townsend discharge-assisted deposition of silica-like films from $SiH_4/N_2O/N_2$ mixtures. A correlation between gas recirculation, discharge instabilities and coating inhomogeneities is brought to the fore. Indeed, in specific discharge cell design, under low flow-rate conditions, the deposit are uniform along the direction perpendicular to the flow while increasing the flow-rate leads to non-uniform thickness profiles along the same direction. This might be an important concern when transferring such a process to an industrial roll-to-roll process for instance, where the width of the substrate can be quite important. With the help of Computational Fluid Dynamics simulation, the penetration of gas recirculation was pointed as a plausible responsible for such a behavior. Hypotheses are proposed in order to explain what could happen.

1. INTRODUCTION

In the industry, low-pressure PECVD is a very commonly used technology especially when deposition on temperature-sensitive substrates such as polymers is required. Nevertheless, this technology has several drawbacks. In addition to its cost, particularly when it comes to deposit on large-area substrates, its transfer to deposit on moving web is very restrictive. Working at atmospheric pressure would certainly lower the global process cost. At the present time, corona discharges are widely used to modify the surface properties of large polymer web. However, corona discharges lead to a stochastic treatment which is satisfying to modify the polymer wettability for instance, but this is definitely not the case when a uniform layer is required. Even if Thyen et al. [1] succeeded in depositing using a corona discharge, their films are not homogeneous. Several other plasma-assisted techniques have been studied to deposit at atmospheric pressure [2, 3, 4, 5, 6, 7], but work is still on progress to make these techniques acceptable for the industry. This paper addresses problems which concern the deposit uniformity in relation to the flow dynamics in the case of a homogeneous Dielectric Barrier Discharge (DBD).

One of the requirements which a deposition process has to satisfy is to lead to uniform films. Of course, this is almost impossible in the direction of the gas flow especially at atmospheric pressure since the consumption of depositing species from the gas entrance in the discharge to its exit inevitably induces at least a variation of the deposition rate, if not a variation of the deposit characteristics [7]. This impediment is easily overcome when the substrate is moving parallel to the gas flow. Then, the variations of the deposit thickness and characteristics are somehow integrated along this direction. However, in a roll-to-roll process for instance, the homogeneity in the direction perpendicular to the moving direction is also important. This direction will be called the width in this paper. If the width is significant, obtaining a uniform film along this direction could be quite a challenge, but concerns other than a too important width can result in a bad homogeneity. This work brings to the fore some links between flow dynamics and the deposit homogeneity. More precisely, starting from the experimental observation of the influence of the gas flow-rate on the deposit homogeneity, our study consists in understanding the origin of this influence mainly by confronting experimental results to flow dynamics simulation results.